PINUS COULTERI AND WILDFIRE ON MOUNT DIABLO, CALIFORNIA

THOMAS R. VALE
Department of Geography, University of Wisconsin, Madison 53706

ABSTRACT

Wildfires burned stands of *Pinus coulteri* on Mt. Diablo, in west-central California, in 1931 and 1977. Trees in woodland vegetation survived the earlier burn but were largely destroyed by the more recent fire, perhaps because of fuel accumulations associated with fire suppression. Coulter pine in brush vegetation suffered mortality in both years. Reproduction of the trees was high after each burn, and little seeding occurred in brush environments except during years following the fires. Policies of fire suppression that lead to high intensity burns in both woodlands and chaparral seem detrimental to the species.

Wildfires typically promote the reproduction of pines (*Pinus*) and restrict the survival of competing species (Mirov, 1967). The relationship between wildfire and *Pinus coulteri* D. Don, a species restricted to central and southern California, however, appears unclear. Several authors have suggested that the range of coulter pine has been restricted by fire, or that the tree has increased with recent suppression of fires (Zobel, 1953; Wilson and Vogl, 1965; Wright, 1968; Griffin, 1976). By contrast, other evidence has indicated that reproduction of coulter pine may be unaffected, or even encouraged, by burning (Wright, 1970; Minnich, 1976; Vogl, 1976). The differing intensities of fires in years prior and subsequent to the initiation of fire suppression may in part account for these apparently contradictory responses (Vogl, 1976).

In the summer of 1976, I began sampling three stands of coulter pine on Mt. Diablo, in west-central California, to determine the effects on the species of a July, 1931, fire (Bowerman, 1944). In July, 1977, a fire again burned two of these areas, and I resampled all three stands in the summer of 1978. This paper evaluates the effects of both fires.

METHODS AND RESULTS

In 1976, the point-quarter method was used to sample the trees along a 900 m east-west traverse of the 30 ha woodland on the north slope of Twin Peaks (Fig. 1:A). The sizes and ages of the coulter pines indicated that the species occurred as an all-aged stand. Half of the 49 measured trees were less than 9 cm dbh, with each increasingly larger 10 cm diameter class represented by fewer individuals; the largest tree encountered had a dbh of 71 cm. Of the 27 coulter pines cored with an increment borer, 13 were more than 45 years of age, and thus had survived the 1931 fire; the oldest tree was more than 104 years of age. Only trees exceeding 28 cm dbh (about 50 years of age) had

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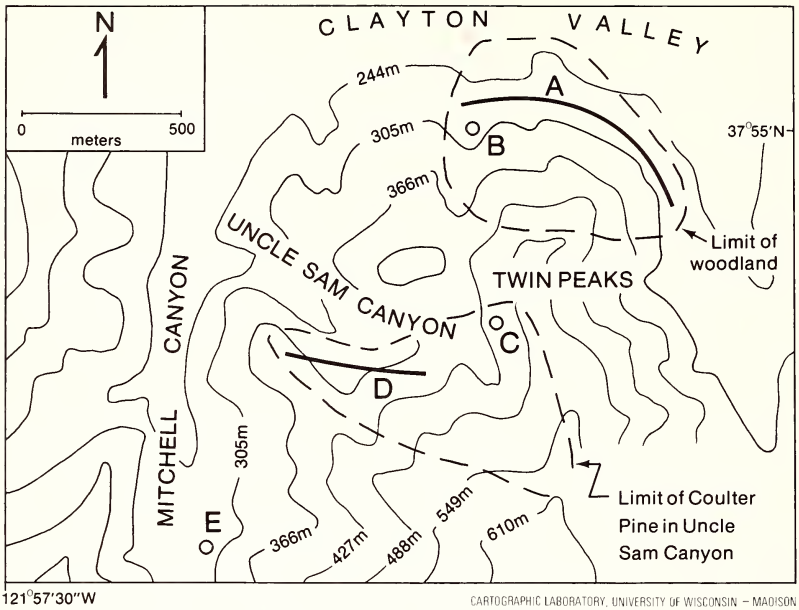

FIG. 1. Contour map of northwest edge of Mt. Diablo, indicating sample sites. A. Traverse of woodland sampled in 1976 and 1978. B. Area of light burn sampled in 1978. C. Area in brush sampled in 1976 and 1978. D. Traverse sampled in 1976. E. Grove sampled in 1976 and revisited in 1978.

heavily charred bark, typically extending 1 to 3 m up the trunks. All trees less than 28 cm dbh were free of charring, implying an absence of fires over the last 50 years. A strong correlation ($r = 0.96$) between size and age suggested that the stand had developed with little competition, and thus in an open woodland. By contrast, sampling showed that the woodland had an understory of *Pinus sabiniana, Quercus agrifolia,* and locally of *P. coulteri,* as well as scattered growth of smaller woody plants. The average distance between all trees in the woodland was 4.9 m, and the basal area per ha for coulter pines was 13.2 m^2 (for all trees, 21 m^2). In spite of dominating the overstory (importance values for tree species in the woodland were *P. coulteri* 140, *Q. agrifolia* 72, *P. sabiniana* 51 and *Q. douglasii* 38), coulter pine was not reseeding throughout the stand: seedlings were restricted to open areas.

The remaining 1976 sampling included coring of all coulter pines along a 350 m traverse of the scattered trees south of the bottom of Uncle Sam Canyon (Fig. 1:D), within a 2 m by 40 m quadrat near the head of that canyon (Fig. 1:C), and along a 50 m traverse of a grove of about 40 trees in Mitchell Canyon (Fig. 1:E). In each of these areas, the coulter pines were associated with heavy brush, notably *Hetero-*

meles arbutifolia, Ptelea crenulata, and *Toxicodendron diversilobum.* In both Uncle Sam and Mitchell canyons, coulter pines were even-aged. Forty of the 41 trees cored had germinated between 1932 and 1950, and one had germinated before 1932. Only two trees, both uncored seedlings in Uncle Sam Canyon, had germinated after 1950. These stands of coulter pine apparently became established shortly after the 1931 fire, which Bowerman (1944) reported as having destroyed most of the trees. For the 26 years after 1950, essentially no reproduction had occurred in these stands in heavy brush.

The 1977 fire swept through most of the Twin Peaks woodland and much of the stand in Uncle Sam Canyon. Unlike the 1931 burn, the recent fire killed most of the coulter pines on Twin Peaks. In June, 1978, sampling by the point-quarter method along the traverse of the woodland studied in 1976 (Fig. 1:A) found only 3 percent of the coulter pines alive. Essentially all of the dead trees retained brown needles, suggesting that the burn was a hot ground fire. The trunks of the trees were charred high into the canopy.

Several other areas on Twin Peaks, not sampled in 1976, were apparently subjected to less intense heat, and supported higher percentages of living trees. The least damaged portion of the woodland, with coulter pines charred but alive, was a strip 20–100 m wide along the northern edge of the stand where the woodland borders the grassland and savanna of Clayton Valley. Two additional areas of ca. 1 ha each, both within the woodland on northwest exposures, also supported many (25–75) living coulter pines. In one of these two small areas near the west edge of the woodland (Fig. 1:B), a survey found nine of 52 coulter pines (17 percent) alive; all trees larger than 40 cm dbh had survived, and all but one smaller than 40 cm dbh were dead. On the living trees, brown needles were restricted to the lower branches, and charred bark extended at most 10 m up the trunks.

Pine seedlings (species could not be identified in these recently-germinated seedlings) were much more common in the woodland after than before the fire. In 1978, they were found in 19 of 34 4m^2 quadrats examined along the traverse of the heavily burned section of the woodland, with an average of one seedling per 8 m^2. Contrarily, in two 40 m traverses within one of the areas of lighter burn, all of 14 samples contained pine seedlings, with an average of two seedlings per m^2. The intense heat in the heavily burned area may have destroyed seeds within the cones of the trees, but the less intense heat in the lightly burned area may have helped to open the cones without destroying the seeds. Seedlings were disproportionately located on sites with much exposed mineral soil; 88 percent of the quadrats with less than 25 percent coverage by organic litter or plants had pine seedlings, and only 29 percent of the quadrats with more than 75 percent of such coverage had pine seedlings.

The sampling indicated that 20 percent of the coulter pines in Uncle

TABLE 1. SUMMARY OF *Pinus coulteri* STAND DATA AFTER 1931 AND 1977 WILDFIRES.

Year	Twin Peaks woodland		Uncle Sam Canyon brush	Mitchell Canyon brush
	A	B		
1976	all-aged stand; mature trees developed without strong competition; seedlings restricted to open areas	not sampled	even-aged stand; trees germinated 1932–1950; very few seedlings	even-aged stand; trees germinated 1932–1950; no seedlings
1977	heavy burn	light burn	spotty burn	not burned
1978	3% of *P. coulteri* alive; seedlings common throughout stand, averaging 1 per $8m^2$; seedlings on mineral soil	17% of *P. coulteri* alive; 7 trees larger than 40 cm dbh alive, and most smaller trees dead; seedlings abundant, averaging 2 per $1m^2$; seedlings on mineral soil	20% of *P. coulteri* alive, but these mostly unburned; most burned trees dead; seedlings scattered, averaging 1 per $10m^2$; seedlings on mineral soil	stand little changed; no healthy seedlings

Sam Canyon (Fig. 1:C) were alive in 1978. The surviving trees were scattered, and most were not burned, apparently reflecting spottiness of the fire. Most of the dead trees were heavily charred and without needles, suggesting an intense crown fire; such a burn is not surprising considering the tall brush and the small stature of the pines in the pre-fire vegetation. The coulter pines at the southern edge of the stand, however, were in a large area that escaped burning in 1977. Only five $4m^2$ quadrats of 18 examined in the burned area had pine seedlings, with an average of one seedling per 10 m^2. Seedlings were restricted to quadrats in which at least 50 percent of the ground area was exposed mineral soil. The paucity of seedlings in Uncle Sam Canyon, even in areas with mineral soil, is a puzzle; it could be related to the destruction of seeds by the fire.

The grove in Mitchell Canyon (Fig. 1:E) was not burned in 1977 and remained a stand of coulter pine emerging above a dense understory of *Heteromeles arbutifolia* and *Quercus agrifolia*. The brush was sufficiently dense to make foot travel difficult. Many of the *Heteromeles* plants were dead but uncharred, suggesting that their deaths occurred after the 1931 fire; the shade cast by the oaks and pines may have been responsible for the shrub mortality. The ground surface within the stand was covered by a thick layer of pine needles and oak leaves. No pine seedlings were found in either 1976 or 1978, except for a few pale, poorly-developed individuals at one locale near the southern edge of the grove in 1978. These data and observations are summarized in Table 1.

Conclusions

This study led me to make several conclusions about coulter pine and wildfire on Mt. Diablo: (1) in the woodland on Twin Peaks, the 1977 fire was apparently much hotter and more destructive than that of 1931. The greater intensity of the more recent fire may have resulted from increased fuel loads caused by successful fire suppression in the years after 1931. This pattern of fire suppression, leading to accumulation of fuels and high intensity burns, is common in forests in the American West (e.g., Kilgore, 1973; Agee et al., 1978); (2) the fires killed coulter pines in the brushy environments in both 1931 and 1977, probably because of abundant fuels in each year. The intensity of fires in chaparral vegetation, as in woodlands or forests, may be greater since initiation of fire suppression (Parsons, 1976), and such hot fires may be responsible for reducing the distribution of certain tree species including *P. coulteri* (Wright, 1968; Vogl, 1976); (3) reproduction by coulter pine in both woodland and brushy vegetation is greatly enhanced by burning that exposes mineral seedbeds (cf. Minnich, 1976; Vogl, 1976); (4) the differential survival of large trees and the enhanced reproduction in less-intensely burned areas both suggest that frequent

light fires may be beneficial to the species in woodland vegetation (cf. Griffin, 1976); and (5) the ecological behavior of coulter pine appears different in differing parts of its ecological range, presumably because of variations in environmental conditions and associated species.

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NOTEWORTHY COLLECTIONS

Polygonum hydropiperoides Michx. (Polygonaceae).—Ecuador, Galápagos Ids., Indefatigable (Santa Cruz) I., S slope, 300 m, moist places, 7 Apr 1930, *Svenson 98* (BKL). Seen through courtesy of the Director, Brooklyn Botanical Garden.

Previous knowledge. Reported under this name by Svenson (Amer. J. Bot. 22:228. 1935): "South slope of the mountain, scattered in a moist ravine at 1000 ft." Erroneously ascribed to Isla Isabela in Wiggins and Porter (*Fl. Galápagos Ids.* 1971). Not otherwise known from the archipelago.

Diagnostic characters. Pl andromonoecious; lvs broad- to linear-lanceolate, ± glabrous except marginally; fls pink to rose; fr perianth oval, completely enclosing achene at maturity.

Significance. Abaxial surfaces of lvs of *Svenson 98* are covered with silvery pustules ("plate glands") typical of *P. opelousanum* Ridd. ex Small (Mitchell, Bull. N. Y. St. Mus. 431:53. 1978). Plate glands do not occur on *P. hydropiperoides*. *P. opelousanum,* more tropical in distribution than *P. hydropiperoides,* has been collected a number of